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PENSOFT

The damsel bug genus *Alloeorhynchus* Fieber, 1860 (Hemiptera, Heteroptera, Nabidae) in Japan

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Abstract. The damsel bug genus *Alloeorhynchus* Fieber, 1860 (Hemiptera, Heteroptera, Nabidae, Prostemmatinae, Prostemmatini) comprises at least 50 species worldwide, and seven species have been recorded from East Asia. In Japan, two species, *A.* (*Alloeorhynchus*) *reinhardi* Kerzhner & Günther, 1999 and *A.* (*A.*) *vinulus* Stål, 1864, are currently known. In this study, *A.* (*A.*) *notatus* Distant, 1919 is reported in Japan for the first time. A geographical color variation of *A.* (*A.*) *vinulus* is reported based on specimens collected from Kume Island in the Ryukyu Islands.

Keywords. East Asia, identification key, new record, Prostemmatinae, Prostemmatini, Ryukyu Islands

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Introduction

The damsel bug genus *Alloeorhynchus* Fieber, 1860 (Hemiptera, Heteroptera, Nabidae, Prostemmatinae, Prostemmatini) comprises two subgenera: the nominotypical *Alloeorhynchus* Fieber, 1860 and *Psilistus* Stål, 1873 (Fieber 1861; Stål 1873; Distant 1904; Reuter and Poppius 1909). Although a list of all species has not been published, at least 50 species are currently known worldwide (cf. Ren 1998; Brailovsky and Barrera 2017; Zhao et al. 2019; Krüger 2019). In East Asia, seven species have been recorded: *A.* (*A.*) *notatus* Distant, 1919 from China and Taiwan; *A.* (*A.*) *reinhardi* Kerzhner & Günther, 1999 from China, Japan, and Korea; *A.* (*A.*) *sinicus* Ren, 1998 from China; *A.* (*A.*) *vinulus* Stål, 1864 from China, Japan, and Taiwan; *A.* (*A.*) *yunnanensis* Zhao, Mao & Cao 2019 from China; *A.* (*P.*) *bakeri* from China; and *A.* (*P.*) *corallinus* from China (Miyamoto 1964; Zheng and Lin 2013; Zhao et al. 2019; Lee et al. 2020; Souma et al. 2022). An identification key has been published only for the Chinese species (Zhao et al. 2019).

For the past 26 years, Ishikawa and our colleagues have collected an indeterminate species of *Alloeorhynchus* from the Ryukyu Islands of Japan (Okinawa, Miyako, Ishigaki, and Iriomote islands), and it has been recorded as "*Alloeorhynchus* sp." (Ishikawa and Miyamoto 2012; Ishikawa 2016). Recently, on the other hand, our colleagues have provided Souma with some dozens of specimens of *A.* (*A.*) *vinulus* from many localities in Japan and with another indeterminate species of the genus from the Ryukyu Islands (Kume Island). After carefully examining the morphological characteristics, we concluded that the indeterminate species, which is widely distributed in the Ryukyu Islands, corresponds to *A.* (*A.*) *notatus*, which was previously unrecorded from Japan. The other indeterminate species, which is found only on Kume Island, is a geographic color variation of *A.* (*A.*) *vinulus*. In this study, we first report *A.* (*A.*) *notatus* from Japan and *A.* (*A.*) *vinulus* from five islands in the Ryukyu Islands (Kuchinoshima, Nakanoshima, Tokunoshima, Kume, and Yonaguni islands). We also report the geographic color variation of *A.* (*A.*) *vinulus*. Furthermore, we provide an illustrated key to facilitate the identification of the three Japanese species of *Alloeorhynchus*.

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Methods

The dried specimens were observed under a stereoscopic microscope (SZ60; Olympus, Tokyo, Japan). To examine the genital characteristics, the male genitalia was removed from the body after softening the specimens in hot water for approximately 10 min. The removed pygophore was immersed in a hot 15% potassium hydroxide (KOH) solution for approximately 5 min. The paramere was removed from the pygophore, which was soaked in 99% ethanol. The pygophore and paramere are preserved in small polyethylene vials containing 50% glycerin and these are mounted on a pin with the individual specimens. Similar dissection methods of heteropteran genitalia using hot water and KOH, as described above, are widely known from previous studies (e.g. Yasunaga et al. 2002, 2018). A digital microscope (Dino-Lite Premier M, Opto Science, Tokyo, Japan) was used for photographing the specimens and obtaining the measurements for the scale bars in the figures. The image stacks obtained with the digital microscope were processed using Adobe Photoshop 2021 v. 22.5.1. Morphological terms were generally assigned according to Zhao et al. (2019).

All Japanese specimens used in this study were deposited in the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka, Japan (ELKU), Kyushu University Museum, Fukuoka, Japan (KUM), Shirakami Research Center for Environmental Sciences, Faculty of Agriculture and Life Science, Hirosaki University, Aomori, Japan (SIHU), and Laboratory of Entomology, Faculty of Agriculture, Tokyo University of Agriculture, Kanagawa, Japan (TUA).

The collection sites of the specimens were mapped using SimpleMappr (Shorthouse 2010). Geographical coordinates were obtained from Google Maps (https://www.google.co.jp/maps), and the map was edited using Adobe Photoshop.

Results

Alloeorhynchus (*Alloeorhynchus*) *notatus* is recorded for the first time in Japan based on nine specimens from the Ryukyu Islands and reported as the third representative of the genus in the country. Additionally, *A.* (*A.*) *vinulus* is newly recorded from five islands in the Ryukyu Islands (Kuchinoshima, Nakanoshima, Tokunoshima, Kume, and Yonaguni islands). A geographic color variation for *A.* (*A.*) *vinulus* is reported based on specimens obtained from Kume Island. A total of three species of the genus *Alloeorhynchus* were recognized in Japan.

Genus *Alloeorhynchus* Fieber, 1860
Subgenus *Alloeorhynchus* Fieber, 1860

Alloeorhynchus (*Alloeorhynchus*) *notatus* Distant, 1919

Figures 1A, 2A, 3A, 4A, 5A, 6A, 7A, 8A, 9A, B

New records. JAPAN – **Ryukyu Islands** • Okinawa, Nago, near Awa, Gajanoko-banta; 26°36′56″N, 127°55′00″E; 24.X.1987; Y. Nishikawa leg.; macropterous 2 ♂, 1 ♀ TUA [NA01TUA–NA03TUA] • Miyako-jima, Hirara; 24°47′05″N, 125°15′49″E; 9.V.2017; Kôichi Arimoto leg.; macropterous 1 ♀ SIHU [NA01SIHU] • Ishigaki Island, Mount Yarabudake; under litter; 24°26′21″N, 124°05′10″E; 24.XI.1997; Keiichi Takahashi leg.; macropterous 1 ♂ KUM [NA01KUM] • as above but 26.XI.1998; macropterous 1 ♂ KUM [NA02KUM] • Iriomote-jima Island, Komi; 24°19′45″N, 123°53′33″E; 7.X.2004; Tadashi Ishikawa leg.; macropterous 1 ♂ TUA [NA04TUA] • Iriomote Island, Uehara; sifting; 24°24′15″N, 123°46′40″E; 25.VI.2019; Yu Hisasue leg.; macropterous 1 ♀ SIHU [NA02SIHU] • Iriomote-jima Island, Shirahama-rindô; alt. 40 m; from leaf litter; 24°22′04″N, 123°45′15″E; 23.III.2020; Ryo Nakamura leg.; macropterous 1 ♂ SIHU [NA03SIHU].

Identification. The nine specimens from Japan recorded above (Figs. 1A, 2A, 3A, 4A, 5A, 6A, 7A, 8A, 9A, B) matched well with the descriptions and illustrations of *A.* (*A.*) *notatus* (Distant 1919; Hsiao 1981; Hsiao and Ren 1981; Kerzhner 1992; Ren 1998) based on coloration and morphological characteristics, especially the shape of the ostiolar peritreme. Therefore, we identified the Japanese specimens as *A.* (*A.*) *notatus*.

Alloeorhynchus (*Alloeorhynchus*) *notatus* resembles *A.* (*A.*) *yunnanensis* in general appearance but is easily distinguished by the following characteristics: corium of forewing with distinctly marking on basal part (obscure marking in *A.* (*A.*) *yunnanensis*); profemur with three distinct tubercles in venter (four distinct tubercles in *A.* (*A.*) *yunnanensis*); and paramere with an angular process in middle part of outer margin (without process in *A.* (*A.*) *yunnanensis*) (Figs. 1A, 2A, 3A, 4A, 9A, B) (Zhao et al. 2019).

A damsel bug species recorded from Japan in previous studies by Ishikawa and Miyamoto (2012) and Ishikawa (2016) as "*Alloeorhynchus* sp." is also *A.* (*A.*) *notatus*.

Distribution. Japan (Ryukyu Islands: Okinawa Island, Miyako Island, Ishigaki Island, Iriomote Island) (Figs. 10, 11) (Ishikawa and Miyamoto 2012; Ishikawa 2016); China (Yunnan Province) (Hsiao 1981; Hsiao and Ren 1981; Ren 1998); India (Distant 1919); Nepal (Kerzhner 1992); Taiwan (Zheng and Lin 2013).

Biology. On the Ryukyu Islands, Japan, *A.* (*A.*) *notatus* was collected from the litter; adults were collected in March, May, June, September, October, and November (Ishikawa and Miyamoto 2012; present study); nymphs were collected in April (Ishikawa and Miyamoto 2012).

Alloeorhynchus (*Alloeorhynchus*) *reinhardi* Kerzhner & Günther, 1999

Figures 1B, 2B, 3B, 4B, 5B, 6B, 7B, 8B, 9C, D

Materials examined. All specimens used in the present study have been recorded by Souma et al. (2022).

Identification. All 11 specimens recorded above have been identified as *A.* (*A.*) *reinhardi* by Souma et al. (2022) based on descriptions by Zhao et al. (2019) and

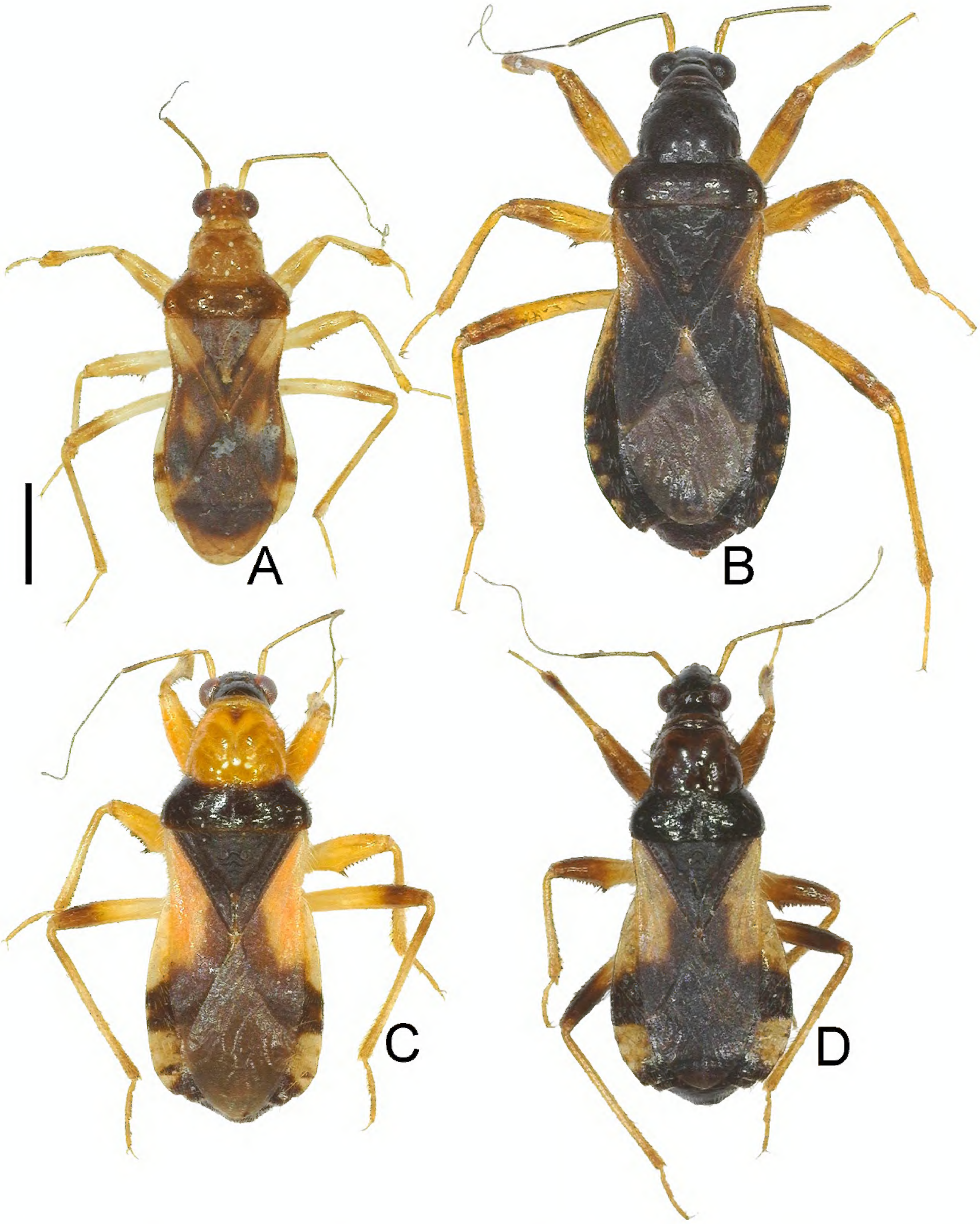

Figure 1. Three species of *Alloeorhynchus* from Japan: male, dorsal view. **A.** *A.* (*Alloeorhynchus*) *notatus* from Okinawa Island, Ryukyu Islands. **B.** *A.* (*A.*) *reinhardi* from Kyushu. **C.** *A.* (*A.*) *vinulus* with typical coloration from Iriomote Island, Ryukyu Islands. **D.** *A.* (*A.*) *vinulus* with dark coloration from Kume Island, Ryukyu Islands. Scale bar: 1.0 mm.

Lee et al. (2020). The present study follows the identification of Souma et al. (2022).

Alloeorhynchus (*Alloeorhynchus*) *reinhardi* resembles *A.* (*A.*) *sinicus* in general appearance but is easily distinguished by the following characteristics: middle part of posterior pronotal lobe dark brown to black (lighter in *A.* (*A.*) *sinicus*); forewing pale brown to dark brown in basal part and dark brown to black in remaining parts (lighter in middle part and brown in remaining parts in *A.* (*A.*) *sinicus*); and paramere curved inward in apical part (curved outward in *A.* (*A.*) *sinicus*) (Figs. 1B, 2B, 9C, D) (Zhao et al. 2019; Souma et al. 2022).

Distribution. Japan (Kyushu) (Figs. 10, 11) (Souma et al. 2022); China (Guizhou Province, Sichuan Province) (Kerzhner and Günter 1999; Zhao et al. 2019); Korea (South Chungcheong Province) (Lee et al. 2020).

Biology. On Kyushu, Japan, *A.* (*A.*) *reinhardi* has been collected from the ground surface of grasslands. Adults were collected in April, May, September, October, and November (Souma et al. 2022).

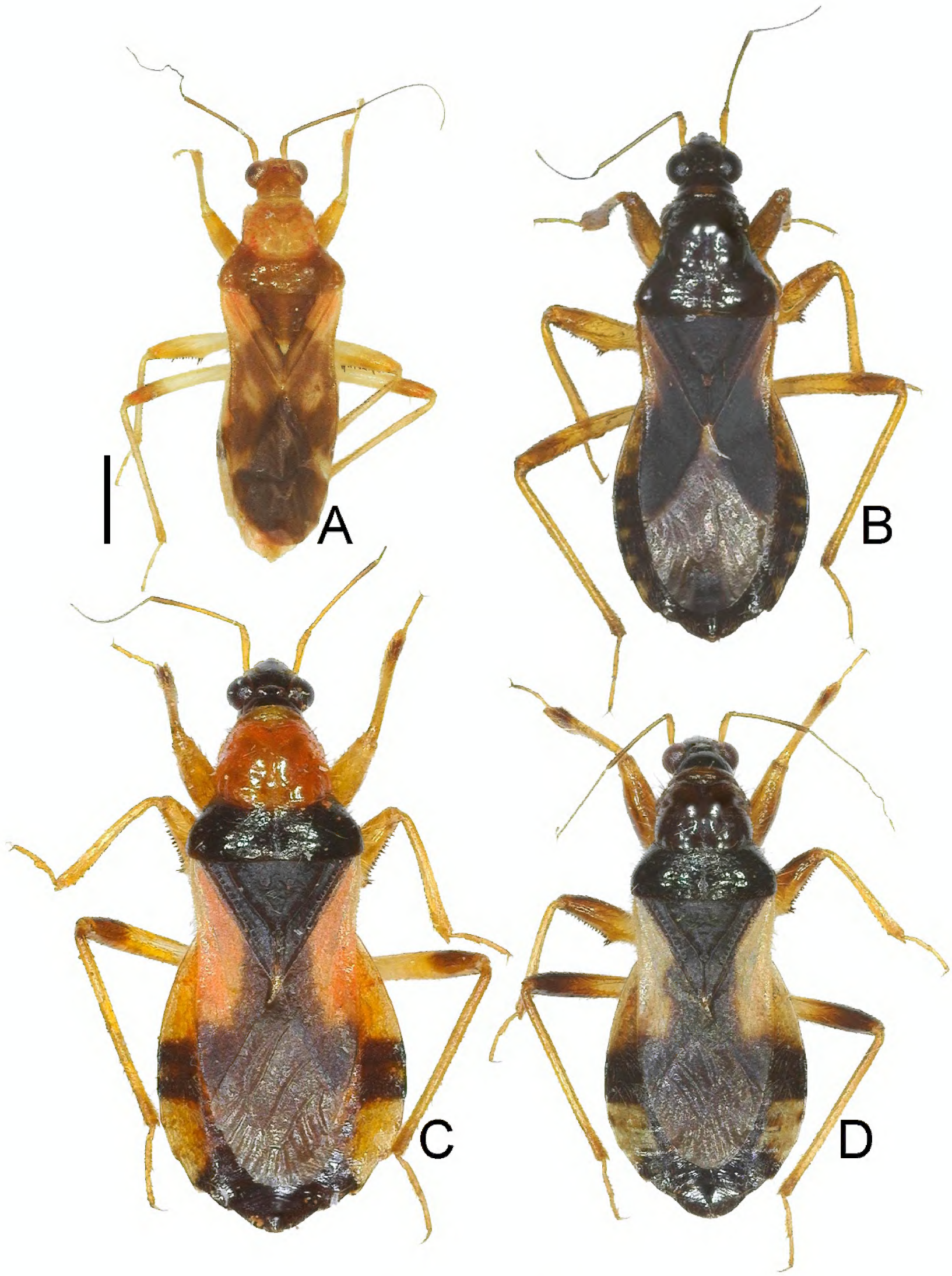

Figure 2. Three species of *Alloeorhynchus* from Japan: female, dorsal view. **A.** *A.* (*Alloeorhynchus*) *notatus* from Okinawa Island, Ryukyu Islands. **B.** *A.* (*A.*) *reinhardi* from Kyushu. **C.** *A.* (*A.*) *vinulus* with typical coloration from Iriomote Island, Ryukyu Islands. **D.** *A.* (*A.*) *vinulus* with dark coloration from Kume Island, Ryukyu Islands. Scale bar: 1.0 mm.

***Alloeorhynchus* (*Alloeorhynchus*) *vinulus* Stål, 1864**

Figures 1C, D, 2C, D, 3C, D, 4C, D, 5C, D, 6C, D, 7C, D, 8C, D, 9E–H

Materials examined. JAPAN – **Kyushu** • Satsuma, Eboshidake; 31°25′29″N, 130°29′42″E; 16.IX.1962; T. Hidaka leg.; macropterous 1 ♀ ELKU [NA01ELKU] • Kagoshima Pref., Minamiôsumi-chô, Satahetsuka; 31° 06′26″N, 130°51′01″E; 19.VII.2020; Reo Ito leg.; macropterous 1 ♂, 1 ♀ SIHU [NA04SIHU, NA05SIHU] – **Koshiki Islands** • Kamikoshiki Island, Suguchi-ike; light trap; 31°50′51″N, 129°53′40″E; 21.VII.2020; Shoichi Imasaka leg.; macropterous 1 ♀ SIHU [NA06SIHU] (referring to Ito et al. 2021) – **Ryukyu Islands** • Yakushima, Anbo; 30°19′08″N, 130°37′48″E; 2.X.1968; Kanmiya leg.; macropterous 1 ♀ KUM [NA03KUM] (referring to Miyamoto 1997) • Kuchinoshima, Hirase; 29°59′52″N, 129°54′43″E; 6.VII.2013; Hiroaki Kojima leg.; macropterous 1 ♂ TUA [NA05TUA] • Nakanoshima, Satsuda; 29°50′14″N, 129°51′17″E; 6.VII.2017;

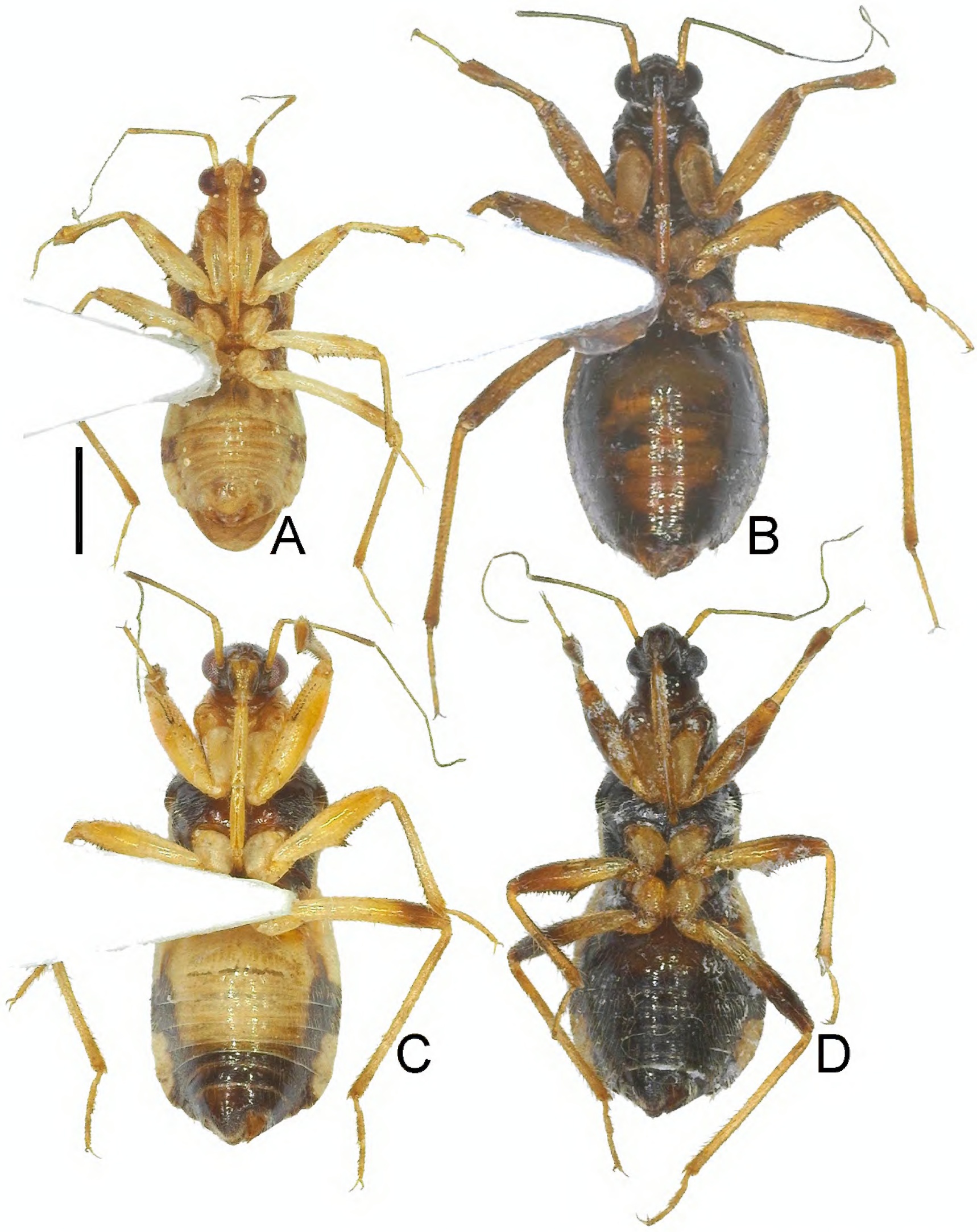

Figure 3. Three species of *Alloeorhynchus* from Japan: male, ventral view. **A.** *A.* (*Alloeorhynchus*) *notatus* from Okinawa Island, Ryukyu Islands. **B.** *A.* (*A.*) *reinhardi* from Kyushu. **C.** *A.* (*A.*) *vinulus* with typical coloration from Iriomote Island, Ryukyu Islands. **D.** *A.* (*A.*) *vinulus* with dark coloration from Kume Island, Ryukyu Islands. Scale bar: 1.0 mm.

Akimi Taoka leg.; macropterous 1 ♂ TUA [NA06TUA] • Amami-Oshima, Naze; 28°23′26″N, 129°29′26″E; 19.VII.1954; Syôiti Miyamoto & Yoshihiro Hirashima leg.; macropterous 1 ♀ ELKU [NA02ELKU] (referring to Miyamoto 1964) • Amami-ôshima Island, Ukenson, Nagara; 28°14′54″N, 129°14′43″E; 6.VII.2005; Tadashi Ishikawa leg.; macropterous 1 ♂, 1 nymph TUA [NA07TUA, NA08TUA] • Amami-ôshima Island, Tatsugô-chô, Kasemamata; 28°24′16″N, 129°36′40″E; 7.VII.2005; Tadashi Ishikawa leg.; macropterous 1 ♂ TUA [NA09TUA] • Tokunoshima Island, Tokunoshima-chô, Tete; 27°52′47″N, 128°55′20″E; 1.XI.2020; Reo Ito leg.; macropterous 1 ♂, 1 ♀ SIHU [NA07SIHU, NA08SIHU] • Okinawa Island, Izumi; 26°39′12″N, 127°56′28″E; 21.X.1963; Syôiti Miyamoto leg.; 1 nymph KUM [NA04KUM] • Okinawa Island, Nago; 26°35′01″N, 128°00′16″E; 22.X.1963; Syôiti Miyamoto leg.; 1 nymph KUM [NA05KUM] • Okinawa-Hontô Island, Yona-Enshûrin; 26°45′47″N, 128°12′57″E; 16–21.IV.1997; Tadashi Ishikawa leg.; macropterous

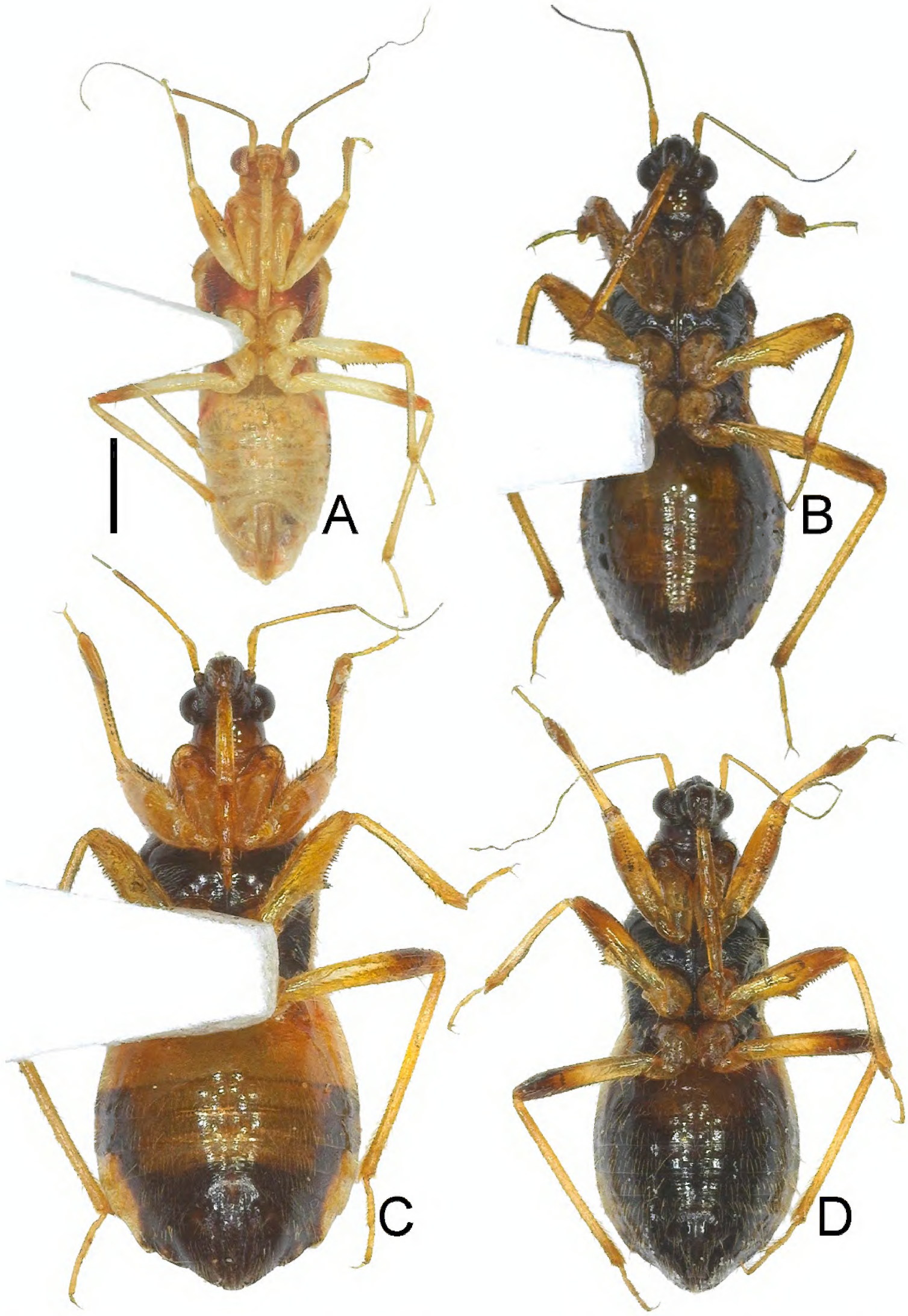

Figure 4. Three species of *Alloeorhynchus* from Japan: female, ventral view. **A.** *A.* (*Alloeorhynchus*) *notatus* from Okinawa Island, Ryukyu Islands. **B.** *A.* (*A.*) *reinhardi* from Kyushu. **C.** *A.* (*A.*) *vinulus* with typical coloration from Iriomote Island, Ryukyu Islands. **D.** *A.* (*A.*) *vinulus* with dark coloration from Kume Island, Ryukyu Islands. Scale bar: 1.0 mm.

1 ♂ TUA [NA10TUA] • Okinawa Island, Urasoe-shi, Urasoe-daikoen; 26°14′53″N, 127°43′53″E; 6.V.2019; Norihide Tokushige leg.; macropterous 1 ♂ SIHU [NA09SIHU] • Okinawa-jima, Kunigami-gun, Ôgimison, Kijoka; 26°42′02″N, 128°08′44″E; 3.X.2021; Yutaro Uehara leg.; macropterous 1 ♀ SIHU [NA10SIHU] • Kume Island, Gima; 26°19′36″N, 126°46′30″E; 16.XI.2012; Kyosuke Okuda leg.; macropterous 1 ♀ SIHU [NA11SIHU] • Kumejima Island, Mount Aradake; 26°18′27″N, 126°47′04″E; 28.IV.2018; Reo Ito leg.; macropterous 1 ♂, 1 ♀ TUA [NA11TUA, NA12TUA] • Miyako Island, Ueno-son, Mount Nobaru-dake; 24°45′58″N, 125°19′33″E; 31.X.1999; Tadashi Ishikawa leg.; macropterous 1 ♂ TUA [NA13TUA] • Miyako Island, Hirara-shi, Nettai-syokubutsuen; 24°48′06″N, 125°18′54″E; 2.XI.1999; Tadashi Ishikawa leg.; macropterous 1 ♂ TUA [NA14TUA] • Miyako Island, Hirara, Higashisokobaru; 24°25′29″N, 124°13′45″E; 3.XI.1999; Tadashi Ishikawa leg.; 1 nymph TUA [NA15TUA] • Ishigaki Island, Maesato, Hegina; light trap; 24°22′54″N,

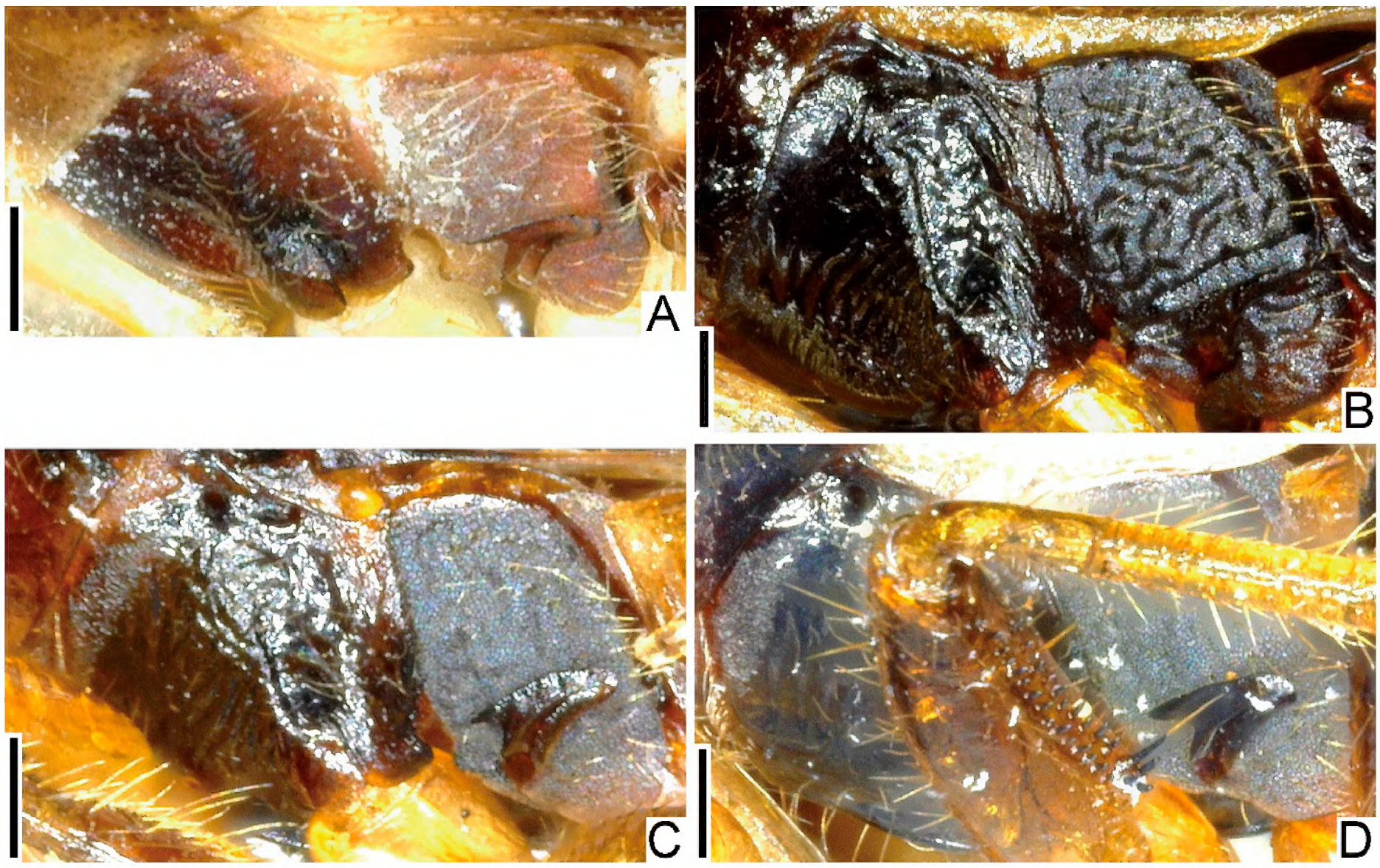

Figure 5. Thoracic pleura of three Japanese species of *Alloeorhynchus*, lateral view. **A.** *A.* (*Alloeorhynchus*) *notatus*. **B.** *A.* (*A.*) *reinhardi*. **C.** *A.* (*A.*) *vinulus* with typical coloration. **D.** *A.* (*A.*) *vinulus* with dark coloration. Scale bars: 0.2 mm.

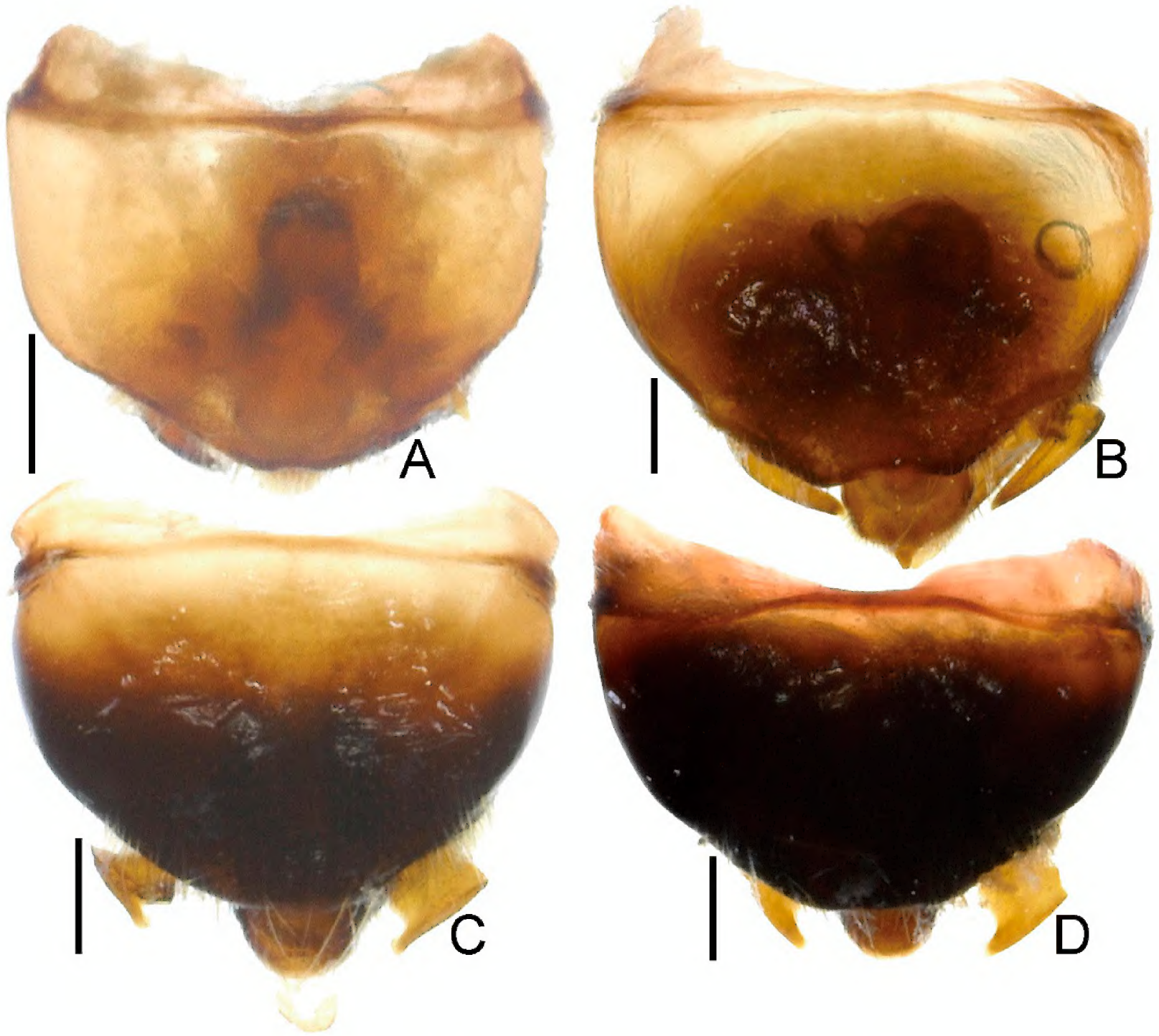

Figure 6. Pygophores of three Japanese species of *Alloeorhynchus*, dorsal view. **A.** *A.* (*Alloeorhynchus*) *notatus*. **B.** *A.* (*A.*) *reinhardi*. **C.** *A.* (*A.*) *vinulus* with typical coloration. **D.** *A.* (*A.*) *vinulus* with dark coloration. Scale bars: 0.2 mm.

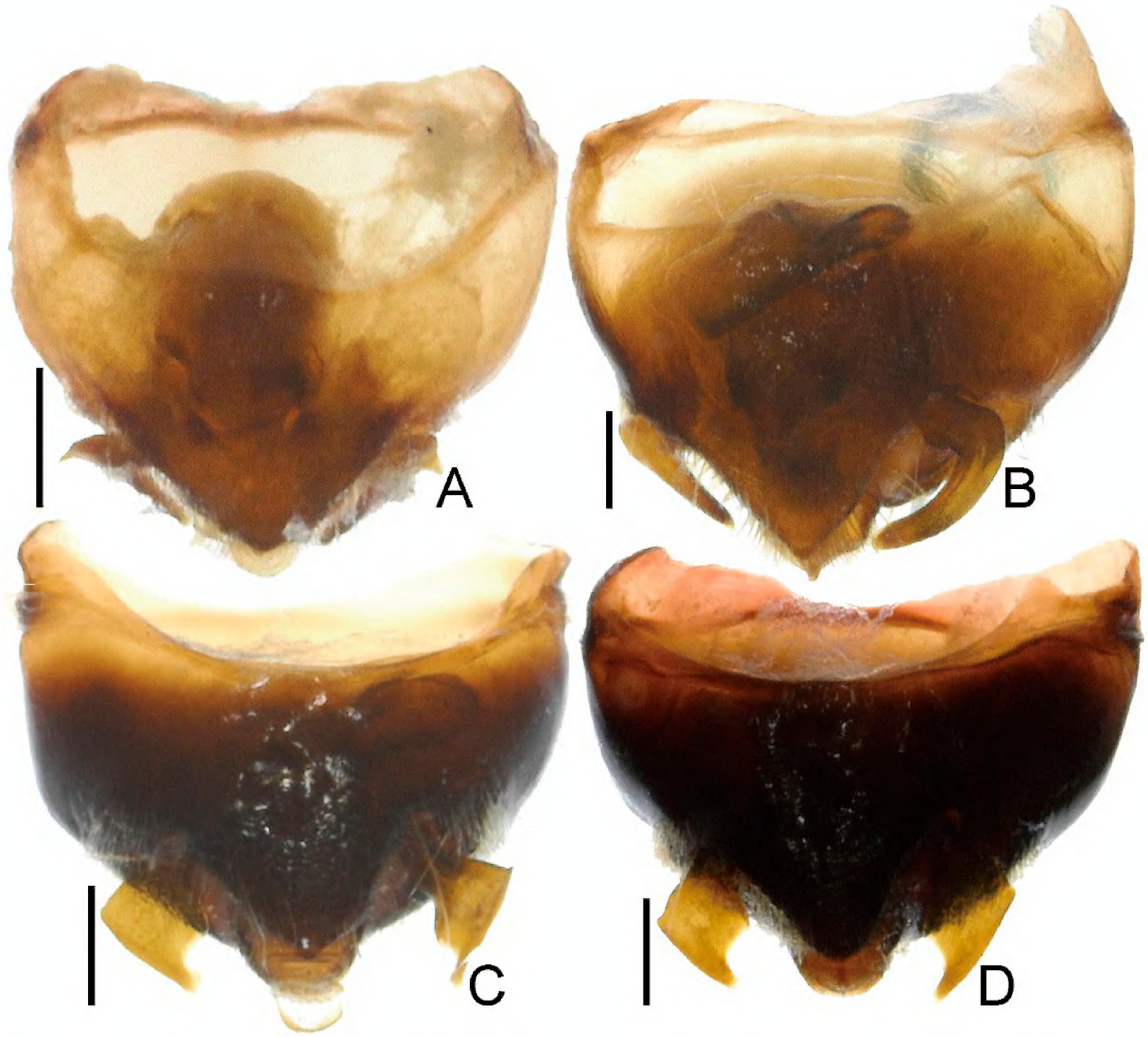

Figure 7. Pygophores of three Japanese species of *Alloeorhynchus*, ventral view. **A.** *A.* (*Alloeorhynchus*) *notatus*. **B.** *A.* (*A.*) *reinhardi*. **C.** *A.* (*A.*) *vinulus* with typical coloration. **D.** *A.* (*A.*) *vinulus* with dark coloration. Scale bars: 0.2 mm.

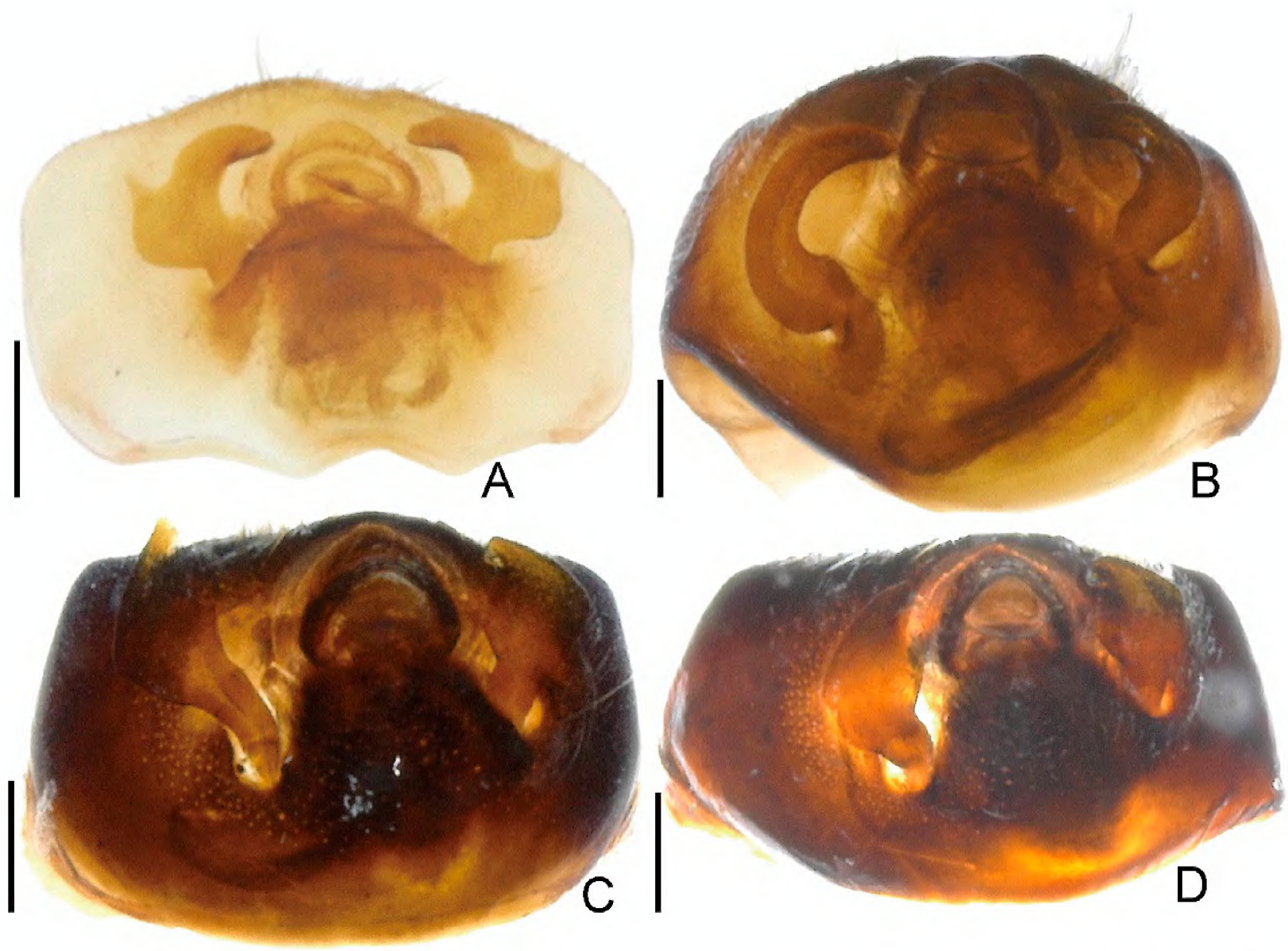

Figure 8. Pygophores of three Japanese species of *Alloeorhynchus*, caudal view. **A.** *A.* (*Alloeorhynchus*) *notatus*. **B.** *A.* (*A.*) *reinhardi*. **C.** *A.* (*A.*) *vinulus* with typical coloration. **D.** *A.* (*A.*) *vinulus* with dark coloration. Scale bars: 0.2 mm.

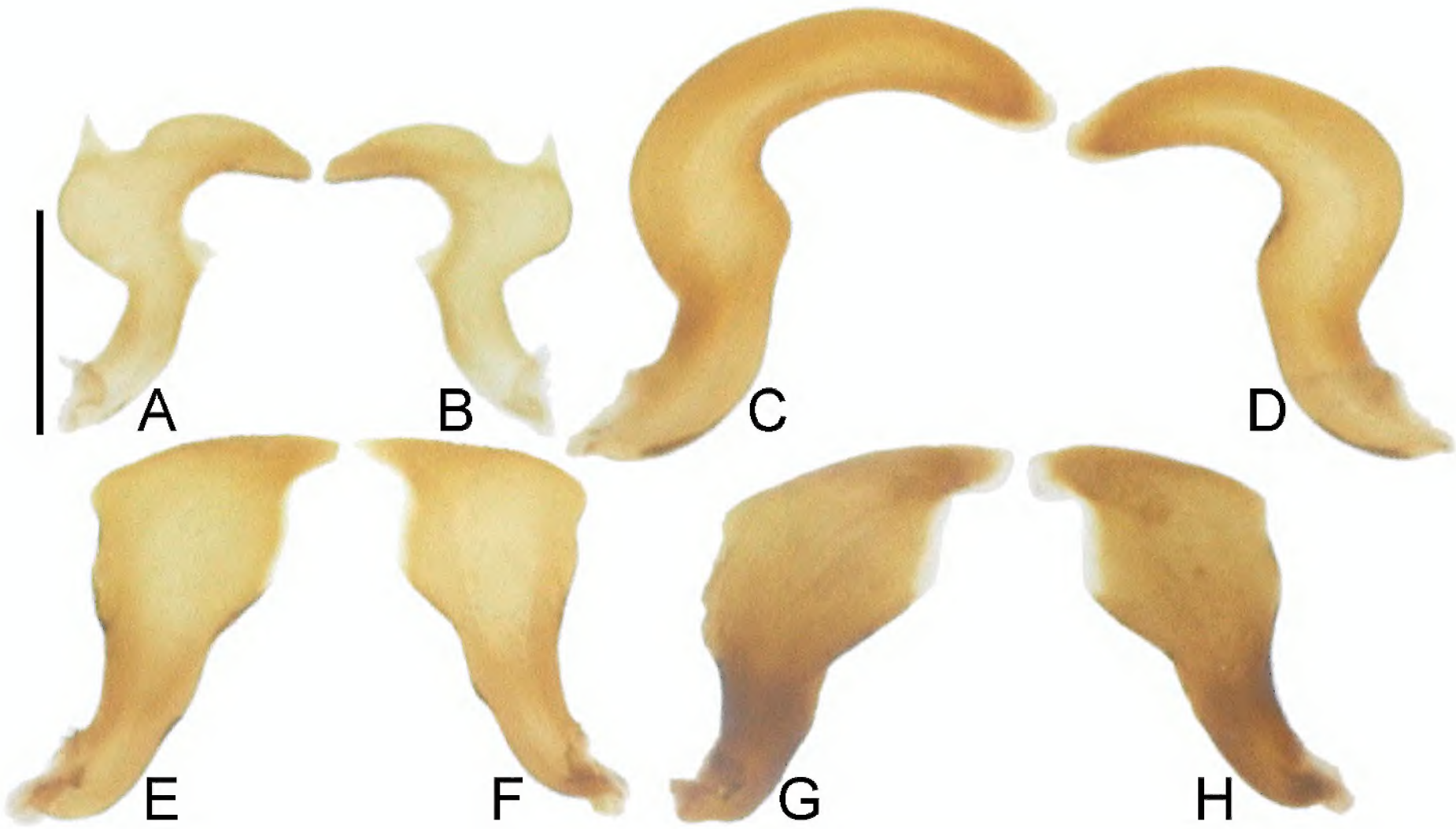

Figure 9. Parameres of three Japanese species of *Alloeorhynchus*, caudal view. **A.** Left paramere of *A.* (*Alloeorhynchus*) *notatus*. **B.** Right paramere of *A.* (*A.*) *notatus*. **C.** Left paramere of *A.* (*A.*) *reinhardi*. **D.** Right paramere of *A.* (*A.*) *reinhardi*. **E.** Left paramere of *A.* (*A.*) *vinulus* with typical coloration. **F.** Right paramere of *A.* (*A.*) *vinulus* with typical coloration. **G.** Left paramere of *A.* (*A.*) *vinulus* with dark coloration. **H.** Right paramere of *A.* (*A.*) *vinulus* with dark coloration. Scale bars: 0.2 mm.

124°11′57″E; 11.VI.1975; collector unknown; macropterous 1 ♂ KUM [NA06KUM] (referring to Miyamoto 1997) • Ishigakijima Island, Omoto, Takeda-rindo; 24°24′45″N, 124°11′17″E; 5.III.2002; Tadashi Ishikawa leg.; macropterous 1 ♀ TUA [NA16TUA] • Ishigakijima Island, Maezato Dam; 24°25′02″N, 124°12′18″E; 15.VI.2002; Tadashi Ishikawa leg.; macropterous 1 ♀ TUA [NA17TUA] • as above but 16.VI.2002; macropterous 3 ♂, 2 ♀ TUA [NA18TUA–NA22TUA] • Ishigaki Island, Maezato; 24°20′13″N, 124°10′59″E; 10.VI.2003; Tadashi Ishikawa leg.; macropterous 1 ♀ TUA [NA23TUA] • Ishigaki Island, Shiraho, foot of Mount Karla-dake; 24°24′33″N, 124°14′55″E; 20.IV.2019; Kyosuke Okuda leg.; macropterous 1 ♀ SIHU [NA12SIHU] • as above but 24.IV.2019; macropterous 1 ♂ SIHU [NA13SIHU] • Iriomote Island, Shirahama; 24°21′35″N, 123°44′47″E; 3.X.1963; Shun-ichi Uéno leg.; macropterous 1 ♂ KUM [NA07KUM] (referring to Miyamoto 1964) • as above but Syôiti Miyamoto leg.; macropterous 1 ♂, 1 nymph KUM [NA08KUM, NA09KUM] (referring to Miyamoto 1964) • Iriomote Island, Sonai; 24°23′23″N, 123°44′51″E; 7.X.1963; Syôiti Miyamoto leg.; macropterous 1 ♂, 1 ♀ KUM [NA10KUM, NA11KUM] (referring to Miyamoto 1964) • Iriomote-jima Island, Toyohara; 24°15′33″N, 123°51′48″E; 11.IV.1997; Hiraku Yoshitake leg.; macropterous 1 ♀ TUA [NA24TUA] • Iriomote-jima Island, Nakano; 24°25′48″N, 123°47′18″E; 29.IV.1998; Koji Toyoda leg.; macropterous 1 ♂, 1 nymph TUA [NA25TUA, NA26TUA] • Iriomote Island, Uehara; light trap; 24°24′15″N, 123°46′40″E; 30.V.1999; Tadashi Ishikawa leg.; macropterous 1 ♀ TUA [NA27TUA] • Iriomote Island, Ôtomi; 24°17′53″N, 123°51′54″E; 1.II.2001; Y. Hirano leg.; macropterous 1 ♀ TUA [NA28TUA] • Iriomote Island, Komi; 24°19′45″N, 123°53′33″E; 2.III.2002; Tadashi Ishikawa leg.; macropterous 2 ♂ TUA [NA29TUA, NA30TUA] • as above but 4.VI.2003; macropterous 1 ♂ TUA [NA31TUA] • as above but 5.VI.2003; macropterous 1 ♂ TUA [NA32TUA] • Iriomote-Island, Funaura; 24°24′33″N, 123°48′26″E; 5.VI.2006; Teruaki Ban leg.; macropterous 1 ♀ TUA [NA33TUA] • as above but 9.IX.2006; Kyohei Watanabe leg.; macropterous 2 ♀ TUA [NA34TUA, NA35TUA] • Yonaguni-jima, near Yonaguni Air Port; 24°27′57″N, 122°58′46″E; 9.IX.2004; Shiho & Koji Arai leg.; macropterous 1 ♀ TUA [NA36TUA].

Identification. *Alloeorhynchus* (*Alloeorhynchus*) *vinulus* was recorded in Japan for the first time by Miyamoto (1964). Most of the specimens recorded above (Figs. 1C, 2C, 3C, 4C, 5C, 6C, 7C, 8C, 9E, F) match well with the previous descriptions and illustrations of *A.* (*A.*) *vinulus* (Stål 1864; Distant 1904; Reuter and Poppius 1909; Hsiao and Ren 1981; Kerzhner 1992; Ren 1998) based on coloration and morphological characteristics. In contrast, three specimens, all from Kume Island in the Ryukyu Islands (Figs. 1D, 2D, 3D, 4D, 5D, 6D, 7D, 8D, 9G, H), differ from previous descriptions and illustrations: anterior pronotal lobe dark brown (pale orange brown to orange in typical coloration of *A.* (*A.*) *vinulus*); corium of forewing pale brown in basal and middle parts (pale orange brown to orange in typical coloration of *A.* (*A.*) *vinulus*); connexivum pale brown

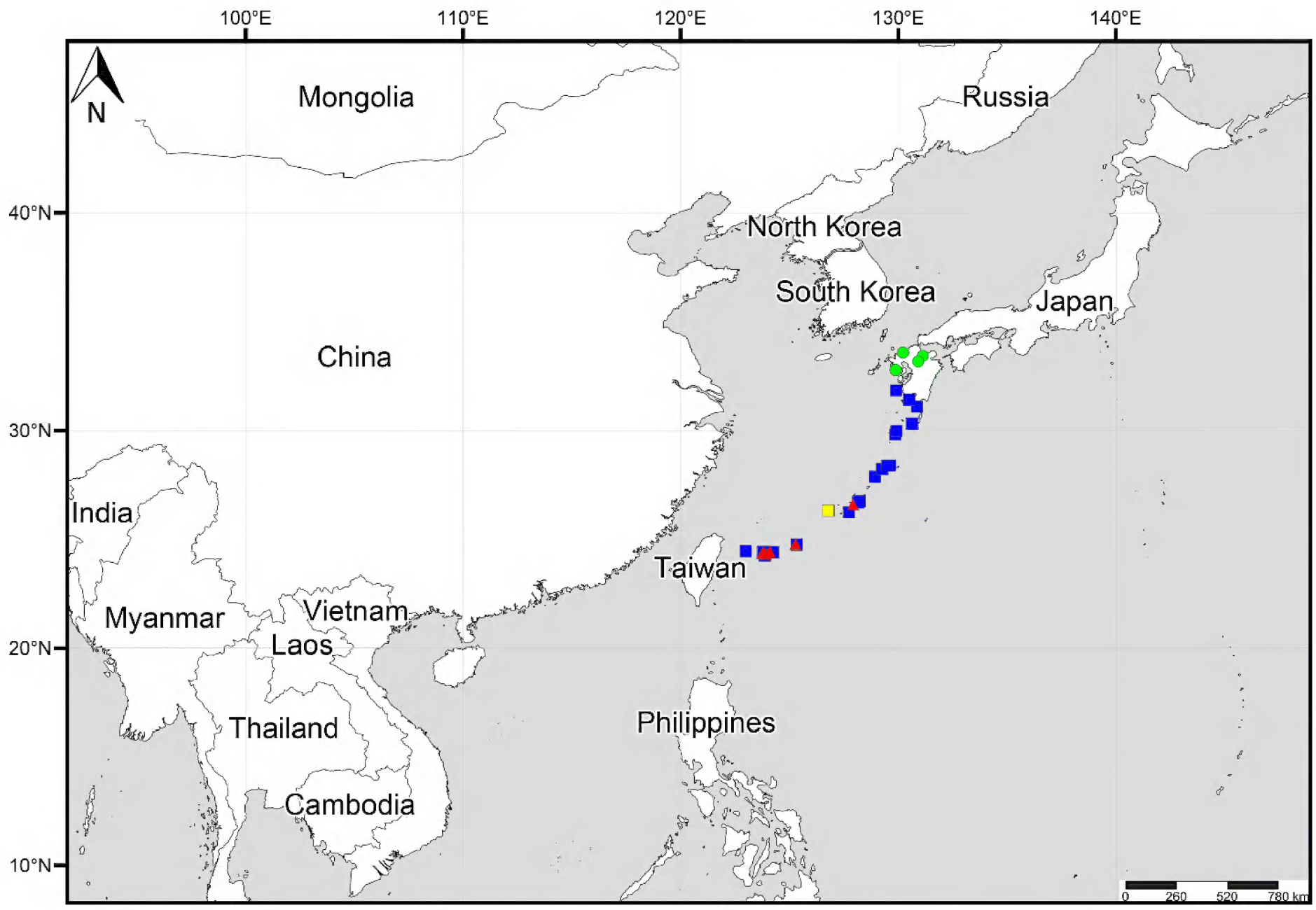

Figure 10. Collection sites of three species of *Alloeorhynchus* from Japan excluding records based on only nymph used in present study. Red triangles = *A.* (*Alloeorhynchus*) *notatus*; green circles = *A.* (*A.*) *reinhardi*; blue squares = *A.* (*A.*) *vinulus* with typical coloration; yellow squares = *A.* (*A.*) *vinulus* with dark coloration.

in anterior and posterior parts (pale orange brown to orange in typical coloration of *A.* (*A.*) *vinulus*); and abdominal sternites II–V dark brown (pale brown to orange in typical coloration of *A.* (*A.*) *vinulus*). Nevertheless, these three specimens from Kume Island with dark coloration matched well with the descriptions and illustrations of *A.* (*A.*) *vinulus* by Kerzhner (1992) and Ren (1998), based on morphological characteristics, including the ostiolar peritreme, pygophore, and paramere. Therefore, we identify all the Japanese specimens recorded above as *A.* (*A.*) *vinulus* and its geographical color variation based on the Kume Island population.

Alloeorhynchus (*Alloeorhynchus*) *vinulus* resembles *A.* (*A.*) *bicoloratus* Distant, 1919 in general appearance but is easily distinguished, as the outer margin of the paramere is not curved inward (curved inward in middle part in *A.* (*A.*) *bicoloratus*) (Fig. 9E–H) (Kerzhner 1992; Ren 1998).

Distribution. Japan (Kyushu; Amakusa Islands: Gesu Island, Shimoshima Island; Koshiki Islands: Kamikoshiki Island, Shimokoshiki Island; Ryukyu Islands: Yakushima Island, Kuchinoshima Island, Nakanoshima Island, Amami-Oshima Island, Tokunoshima Island, Okinawa Island, Kume Island, Miyako Island, Tarama Island, Ishigaki Island, Iriomote Island, Yonaguni Island) (Figs. 10, 11) (Miyamoto 1964, 1997; Ishikawa and Miyamoto 2012; Ishikawa 2016; Nozaki et al. 2015, 2016; Aoyagi 2018; Ito et al. 2021; Miyazaki et al. 2020); China (Hainan Island) (Hsiao and Ren 1981; Ren 1998); India (Distant 1904; Reuter and Poppius 1909); Indonesia (Java Island) (Stål 1864); Myanmar (Distant 1904); Philippines (Stål 1871); Taiwan (Zheng and Lin 2013); Vietnam (Ren 1998).

Biology. Adults have been collected in Japan throughout the year, whereas nymphs have been collected in April, July, October, and November (Miyamoto 1964; Ishikawa and Miyamoto 2012; Nozaki et al. 2015, 2016; Aoyagi 2018; Ito et al. 2021; Miyazaki et al. 2020; present study).

Key to the species of *Alloeorhynchus* occurring in Japan

1 Corium of forewing black in middle part (Figs. 1B, 2B); connexivum black in inner half of posterior part; left paramere larger than right paramere (Fig. 9C, D) ..... *A.* (*A.*) *reinhardi* Kerzhner & Günther, 1999

— Corium of forewing at least partly pale brown to orange in middle part (Figs. 1A, C, D, 2A, C, D); connexivum pale brown to orange in inner half of posterior part; left paramere as large as right paramere (Fig. 9A, B, E–H) 2

2 Head pale brown to orange (Figs. 1A, 2A); corium of forewing pale brown to orange at apex; ostiolar peritreme less protruding dorsolaterad (Fig. 5A); paramere with an angular process in middle part of outer margin (Fig. 9A, B) ..... *A.* (*A.*) *notatus* Distant, 1919

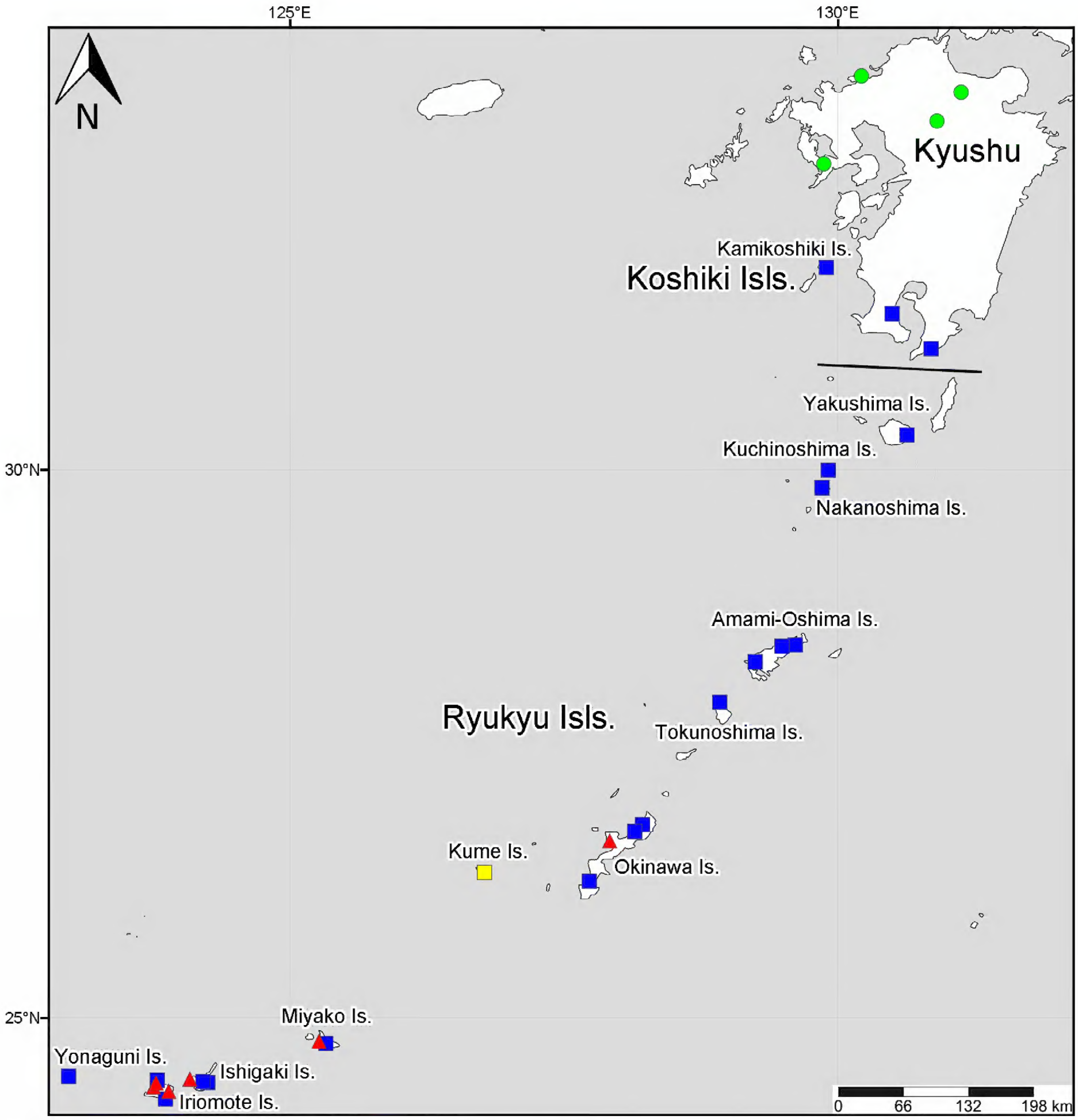

Figure 11. Detailed collection sites of three species of *Alloeorhynchus* from Japan excluding records based on only nymph used in present study. Red triangles = *A.* (*Alloeorhynchus*) *notatus*; green circles = *A.* (*A.*) *reinhardi*; blue squares = *A.* (*A.*) *vinulus* with typical coloration; yellow squares = *A.* (*A.*) *vinulus* with dark coloration.

— Head black (Figs. 1C, D, 2C, D); corium of forewing black at apex; ostiolar peritreme more protruding dorsolaterad (Fig. 5C, D); paramere without process in middle part of outer margin (Fig. 9E–H) .... *A.* (*A.*) *vinulus* Stål, 1864

Discussion

To date, *Alloeorhynchus* (*A.*) *notatus* has not been recorded in regons east of Taiwan (Distant 1919; Hsiao 1981; Hsiao and Ren 1981; Kerzhner 1992; Ren 1998; Zheng and Lin 2013). Similarly, *A.* (*A.*) *reinhardi* and *A.* (*A.*) *vinulus* have not been recorded in regions east of Japan (Miyamoto 1964; Ren 1998; Zheng and Lin 2013; Zhao et al. 2019; Lee et al. 2020; Souma et al. 2022). Therefore, Okinawa Island in Japan is the easternmost locality of *A.* (*A.*) *notatus*, and Kyushu in Japan is the easternmost locality of *A.* (*A.*) *reinhardi* and *A.* (*A.*) *vinulus* (Figs. 10, 11). Conclusively, the Japanese archipelago is considered to be a marginal region for the distribution of these three species of *Alloeorhynchus*, which are widely distributed in East Asia (Stål 1864; Distant 1919; Kerzhner and Günter 1999; Lee et al. 2020).

The geographic color variation in *Alloeorhynchus* species has already been reported for *A.* (*A.*) *reinhardi* based on the Kyushu population (Souma et al. 2022). Our study also discovered color variation for *A.* (*A.*) *vinulus* based on the population from Kume Island. Therefore, future molecular phylogeographic study may reveal genetic differences among islands and mainland

populations of *Alloeorhynchus* species occurring in Japan.

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Author Contributions

Conceptualization: JS. Data curation: JS. Funding acquisition: JS. Investigation: JS. Methodology: JS. Project administration: TI, JS. Resources: JS. Software: JS. Supervision: TI, JS. Validation: JS. Visualization: JS. Writing – original draft: JS. Writing – review and editing: TI, JS.

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